

CLAIMS

[1] A method of controlling pressure in an electric injection molding machine, comprising:

detecting an angular velocity ω of a motor operative to propel forward a screw in an injection molding machine;

deriving an estimated melt pressure value δ^{\wedge} , based on an observer, from said detected angular velocity ω of said motor and a torque command value T^{CMD} given to said motor; and

controlling said motor such that said estimated melt pressure value δ^{\wedge} follows a melt pressure setting δ^{REF} .

[2] The method of controlling pressure in an electric injection molding machine according to claim 1, wherein said observer is represented by the following Expression 1.

[Expression 1]

$$\frac{d}{dt} \begin{pmatrix} \omega^{\wedge} \\ \delta^{\wedge} \end{pmatrix} = \begin{pmatrix} d_1 & 1/J \\ d_2 & 0 \end{pmatrix} \begin{pmatrix} \omega^{\wedge} \\ \delta^{\wedge} \end{pmatrix} + \begin{pmatrix} 1/J \\ 0 \end{pmatrix} T^{CMD} + \begin{pmatrix} 1/J \\ 0 \end{pmatrix} F(\omega) - \begin{pmatrix} d_1 \\ d_2 \end{pmatrix} \omega$$

where ω^{\wedge} : Estimated value of Angular velocity of Motor

d_1, d_2 : Certain coefficients

J : Inertia moment over Injection mechanism

$F(\omega)$: Dynamic frictional resistance and Static frictional resistance over Injection mechanism

[3] The method of controlling pressure in an electric injection molding machine according to claim 1, wherein said observer is represented by the following Expression 2.

[Expression 2]

$$\begin{aligned} \omega^{\wedge} &= \omega^{\wedge}_{-1} + \{d_1(\omega^{\wedge}_{-1} - \omega) + (1/J)(T^{CMD}_{-1} + \delta^{\wedge}_{-1} + F(\omega))\} dt \\ \delta^{\wedge} &= \delta^{\wedge}_{-1} + \{d_2(\omega^{\wedge}_{-1} - \omega)\} dt \end{aligned}$$

where $\hat{\omega}$: Estimated value of Angular velocity of Motor
 d_1, d_2 : Certain coefficients
 J : Inertia moment over Injection mechanism
 $F(\omega)$: Dynamic frictional resistance and Static frictional resistance over Injection mechanism
 x_{-1} : Value of x at Immediately preceding processing period

[4] The method of controlling pressure in an electric injection molding machine according to claim 1,

wherein said screw in said injection molding machine and said motor are coupled together via a belt suspended around pulleys mounted on respective rotation shafts, and

wherein said observer is represented by the following Expression 3.

[Expression 3]

$$\frac{d}{dt} \begin{pmatrix} \hat{\omega}^M \\ \hat{\omega}^L \\ \hat{F} \\ \hat{\delta} \\ \hat{\sigma} \end{pmatrix} = \begin{pmatrix} d_1 & 0 & -\frac{R^M}{J^M} & 0 & 0 \\ d_2 & 0 & \frac{R^L}{J^L} & \frac{1}{J^L} & 0 \\ d_3 + K_b R^M & -K_b R^L & 0 & 0 & 0 \\ d_4 & K_w & \frac{K_{wd} R^L}{J^L} & \frac{K_{wd}}{J^L} & 1 \\ d_5 & 0 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} \hat{\omega}^M \\ \hat{\omega}^L \\ \hat{F} \\ \hat{\delta} \\ \hat{\sigma} \end{pmatrix} + \begin{pmatrix} \frac{1}{J^M} \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} T^{CMD} + \begin{pmatrix} 0 \\ \frac{1}{J^L} \\ 0 \\ \frac{K_{wd}}{J^L} \\ 0 \end{pmatrix} F_d(\omega^L) - \begin{pmatrix} d_1 \\ d_2 \\ d_3 \\ d_4 \\ d_5 \end{pmatrix} \omega^M$$

where d_1 - d_5 : Certain coefficients

J^M : Inertia moment at Motor side

ω^M : Angular velocity of Motor

R^M : Pulley radius at Motor side

F : Tension of Belt

K_b : Spring constant of Belt

J^L : Inertia moment at Screw side

ω^L : Angular velocity at Screw side

R^L : Pulley radius at Screw side

$F_d(\omega^L)$: Dynamic frictional resistance at Screw side

K_w : Elastic modulus of Resin

K_{wd} : Coefficient of Viscosity of Resin

σ : Force of Screw pushing Resin

[5] The method of controlling pressure in an electric injection molding machine according to claim 1,

wherein said screw in said injection molding machine and said motor are coupled together via a belt suspended around pulleys mounted on respective rotation shafts, and

wherein said observer is represented by the following Expression 4.

[Expression 4]

$$\begin{aligned}\dot{\omega}^M &= \dot{\omega}^M_{-1} + \left\{ d_1 (\dot{\omega}^M_{-1} - \omega^M) + \frac{1}{J^M} (T^{CMD}_{-1} - R^M \hat{F}_{-1}) \right\} dt \\ \dot{\omega}^L &= \dot{\omega}^L_{-1} + \left\{ d_2 (\dot{\omega}^M_{-1} - \omega^M) + \frac{1}{J^L} (R^L \hat{F}_{-1} + \hat{\delta}_{-1} + F_d(\omega^L)) \right\} dt \\ \hat{F} &= \hat{F}_{-1} + \left\{ d_3 (\dot{\omega}^M_{-1} - \omega^M) + K_b (R^M \dot{\omega}^M_{-1} - R^L \dot{\omega}^L_{-1}) \right\} dt \\ \hat{\delta} &= \hat{\delta}_{-1} + \left\{ d_4 (\dot{\omega}^M_{-1} - \omega^M) + K_w \dot{\omega}^L_{-1} + \frac{K_{wd}}{J^L} (R^L \hat{F}_{-1} + \hat{\delta}_{-1} + F_d(\omega^L)) + \sigma_{-1} \right\} dt \\ \sigma &= \sigma_{-1} + d_5 (\dot{\omega}^M_{-1} - \omega^M) dt\end{aligned}$$

where d_1 - d_5 : Certain coefficients

J^M : Inertia moment at Motor side

ω^M : Angular velocity of Motor

R^M : Pulley radius at Motor side

F : Tension of Belt

K_b : Spring constant of Belt

J^L : Inertia moment at Screw side

ω^L : Angular velocity at Screw side

R^L : Pulley radius at Screw side

$F_d(\omega^L)$: Dynamic frictional resistance at Screw side

K_w : Elastic modulus of Resin

K_{wd} : Coefficient of Viscosity of Resin

σ : Force of Screw pushing Resin

x_{-1} : Value of x at Immediately preceding processing period

[6] The method of controlling pressure in an electric injection molding machine according to claim 1,

wherein said screw in said injection molding machine and said motor are coupled together via a belt suspended around pulleys mounted on respective rotation shafts, and

wherein said observer is represented by the following Expression 5.

[Expression 5]

$$\frac{d}{dt} \begin{pmatrix} \hat{\omega}^M \\ \hat{\omega}^L \\ \hat{F} \\ \hat{\delta} \end{pmatrix} = \begin{pmatrix} d_1 & 0 & -\frac{R^M}{J^M} & 0 \\ d_2 & 0 & \frac{R^L}{J^L} & \frac{1}{J^L} \\ d_3 + K_b R^M & -K_b R^L & 0 & 0 \\ d_4 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} \hat{\omega}^M \\ \hat{\omega}^L \\ \hat{F} \\ \hat{\delta} \end{pmatrix} + \begin{pmatrix} \frac{1}{J^M} \\ 0 \\ 0 \\ 0 \end{pmatrix} T^{CMD} + \begin{pmatrix} 0 \\ \frac{1}{J^L} \\ 0 \\ 0 \end{pmatrix} F_d(\omega^L) - \begin{pmatrix} d_1 \\ d_2 \\ d_3 \\ d_4 \end{pmatrix} \omega^M$$

where d_1 - d_4 : Certain coefficients

J^M : Inertia moment at Motor side

ω^M : Angular velocity of Motor

R^M : Pulley radius at Motor side

F : Tension of Belt

K_b : Spring constant of Belt

J^L : Inertia moment at Screw side

ω^L : Angular velocity at Screw side

R^L : Pulley radius at Screw side

$F_d(\omega^L)$: Dynamic frictional resistance at Screw side

[7] The method of controlling pressure in an electric injection molding machine according to claim 1,

wherein said screw in said injection molding machine and said motor are coupled together via a belt suspended around pulleys mounted on respective rotation shafts, and

wherein said observer is represented by the following Expression 6.

[Expression 6]

$$\begin{aligned}\dot{\omega}^M &= \dot{\omega}^M_{-1} + \left\{ d_1 (\dot{\omega}^M_{-1} - \omega^M) + \frac{1}{J^M} (T^{CMD}_{-1} - R^M \hat{F}_{-1}) \right\} dt \\ \dot{\omega}^L &= \dot{\omega}^L_{-1} + \left\{ d_2 (\dot{\omega}^M_{-1} - \omega^M) + \frac{1}{J^L} (R^L \hat{F}_{-1} + \hat{\delta}_{-1} + F_d(\omega^L)) \right\} dt \\ \hat{F} &= \hat{F}_{-1} + \left\{ d_3 (\dot{\omega}^M_{-1} - \omega^M) + K_b (R^M \dot{\omega}^M_{-1} - R^L \dot{\omega}^L_{-1}) \right\} dt \\ \hat{\delta} &= \hat{\delta}_{-1} + d_4 (\dot{\omega}^M_{-1} - \omega^M) dt\end{aligned}$$

where d_1 - d_4 : Certain coefficients

J^M : Inertia moment at Motor side

ω^M : Angular velocity of Motor

R^M : Pulley radius at Motor side

F : Tension of Belt

K_b : Spring constant of Belt

J^L : Inertia moment at Screw side

ω^L : Angular velocity at Screw side

R^L : Pulley radius at Screw side

$F_d(\omega^L)$: Dynamic frictional resistance at Screw side

x_{-1} : Value of x at Immediately preceding processing period

[8] The method of controlling pressure in an electric injection molding machine according to claim 3, 5 or 7, further comprising:

calculating said torque command value T^{CMD} for said motor based the following Expression 7; and

feeding back said torque command value to said motor.

[Expression 7]

$$T^{CMD} = k_p (\delta^{REF} - \delta^*) + \alpha$$

where k_p : Certain constant

α : Certain function or constant

[9] An apparatus for controlling pressure in an electric injection molding machine, comprising:

an observer arithmetic unit operative to derive an estimated melt pressure value δ^* , based on an observer, from an angular velocity ω of a motor operative to propel forward a screw in an injection molding machine and a torque command value T^{CMD} given to said motor; and

a torque arithmetic unit operative to calculate said torque command value T^{CMD} for said motor using said estimated melt pressure value δ^* derived at said observer arithmetic unit and feed back said torque command value to said motor.

[10] The method of controlling pressure in an electric injection molding machine according to claim 1, further comprising deriving a dynamic frictional resistance $F(\omega)$ from a relation between a velocity or position and a torque or current value associated with said motor at the time of injection with no resin loaded.

[11] The method of controlling pressure in an electric injection molding machine according to claim 1, further comprising:

defining a dynamic frictional resistance $F(\omega)$ as a sum of a velocity-dependent component and a load-dependent component;

deriving said velocity-dependent component of said dynamic frictional resistance from a relation between a velocity or position and a torque or current value associated with said motor at the time of injection with no resin loaded; and

deriving said load-dependent component of said dynamic frictional resistance from a relation between a

torque or current value and a pressure value at the time of injection with a plugged nozzle.